High Power Electromagnetic Wave Heating in the ITER Burning Plasma

NCCS USERS MEETING

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Project Overview

- **Project participants**
  - Fred Jaeger, Lee Berry, Don Batchelor (FED), Vickie Lynch, Ed D'Azevedo (NCCS), Bob Harvey (COMPX), Paul Bonoli (MIT)
- **Brief summary**
  - We propose to extend previous electromagnetic wave heating calculations (AORSA-CQL3D) to the burning plasma regime of ITER.
  - ITER is the next step toward fusion as a practical energy source and will be capable of self-sustained fusion reactions or "burning plasma"
  - The extension to ITER is difficult because the physical size of ITER and the high plasma density require an order of magnitude increase in resolution over previous calculations.
- **Project milestones**
  - First full-wave simulations of mode conversion in ITER
  - First calculations of the evolution of non-thermal tritium and fusion-born alpha particles simultaneously in ITER with wave heating
  - First calculation of the 3D wave electric fields and current drive in ITER using a sum over a spectrum of 2D solutions

Project impact

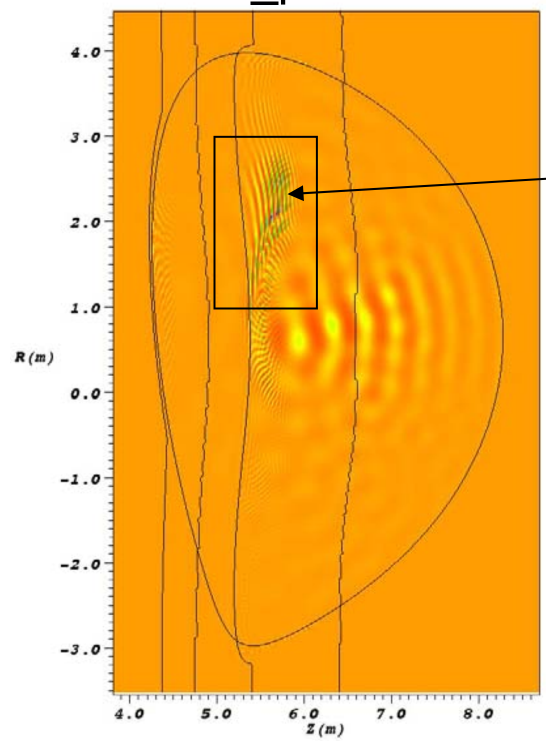
- **What can be solved from the results?**
  - Accurately predict the electromagnetic wave heating, current drive, and flow deposition that can be used to control the ITER plasma
  - Determine the spectrum of waves launched into the ITER plasma from realistic 3D launching structures (antennas)
  - Treat the nonlinear coupling between the waves and the energetic ion populations or “ion tails” in the plasma (for ITER this includes the fusion alpha particles)
- **Who cares about this work and its results? Why?**
  - Those designing and planning the ITER device that will be built in Cadarach, France by EU, Japan, USA and Russia.
  - High power electromagnetic waves have the potential to heat and control the burning plasma in ITER
  - But to realize this potential, it is essential to have both a theoretical understanding and accurate modeling of these processes

Project logistics

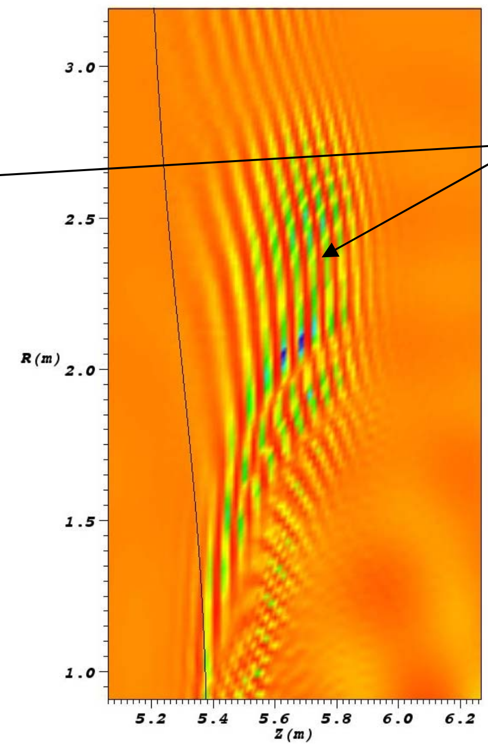
- **What size production jobs will you be running?**

  Mode conversion in ITER takes 4096 processors for 1.5 hrs on XT3 (350x350 mesh for Maxwellian ions and a single toroidal mode)

*E*_parallel



Blowup (*E*_parallel)

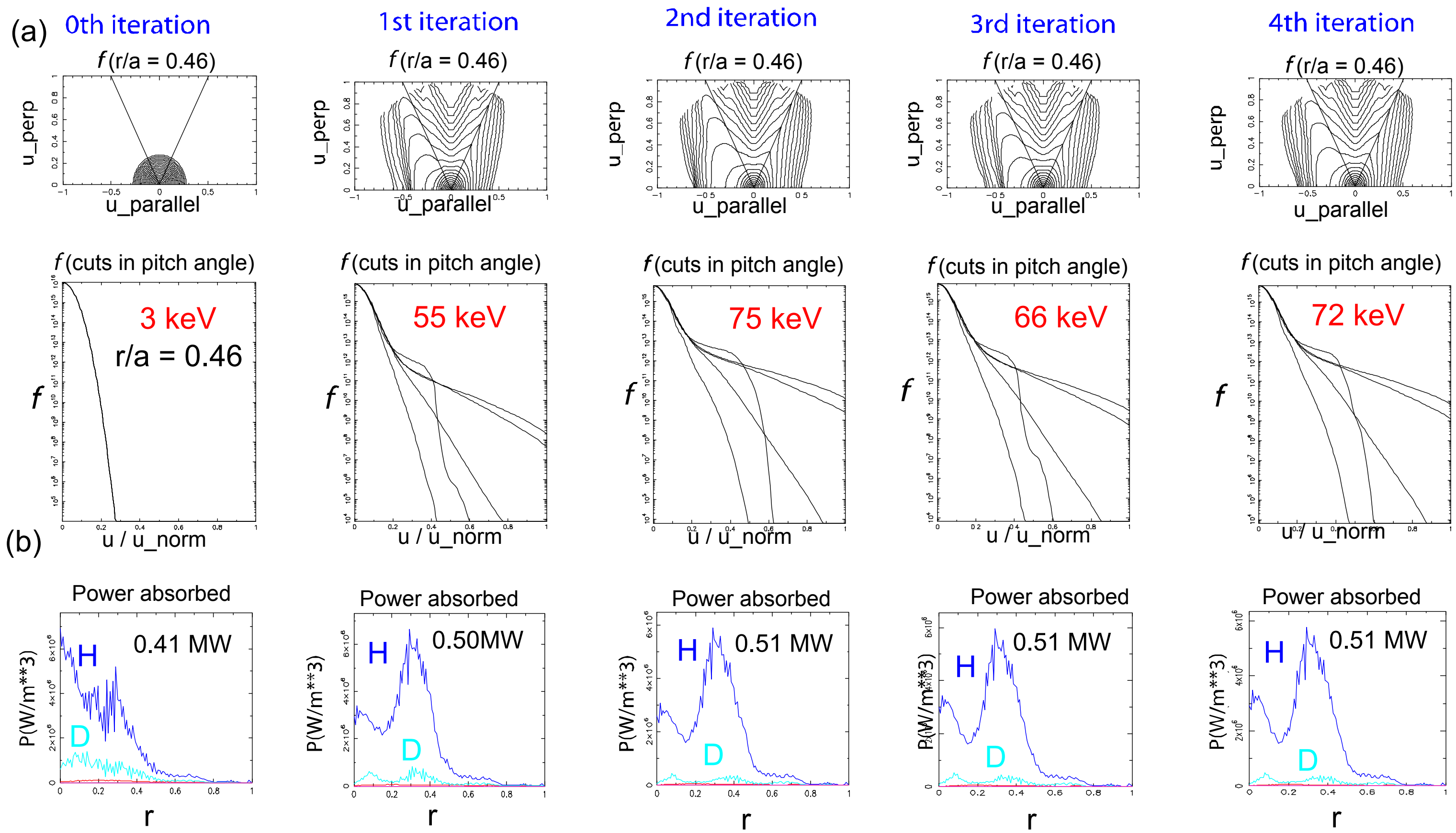


Mode converted Ion Cyclotron Wave (ICW)

Project logistics

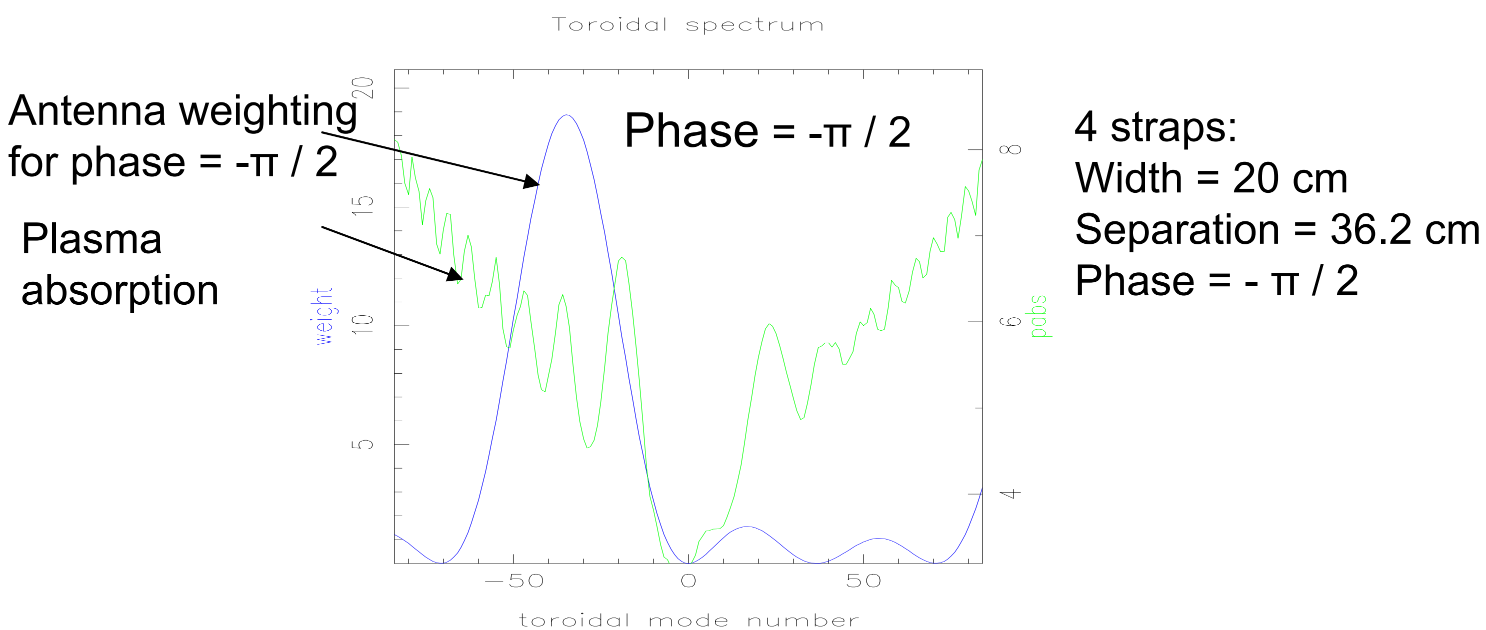
- **What size production jobs will you be running?**

Self-consistent quasilinear heating takes 1024 processors for 8 hrs on XT3 (AORSA-CQL3D for single non-Maxwellian ion on 256x256 mesh)



Project logistics

- **What size production jobs will you be running?**
  - Calculate the 3D wave electric fields in ITER using a sum over a spectrum of 2D solutions (169 toroidal modes): requires 2048 processors for 8 hrs on the XT3 (128x128 mesh, all Maxwellian ions)



  - 169 toroidal modes for mode conversion (350x350) would take 1,000,000 processor hours, or twice the allocation for this project

Project logistics

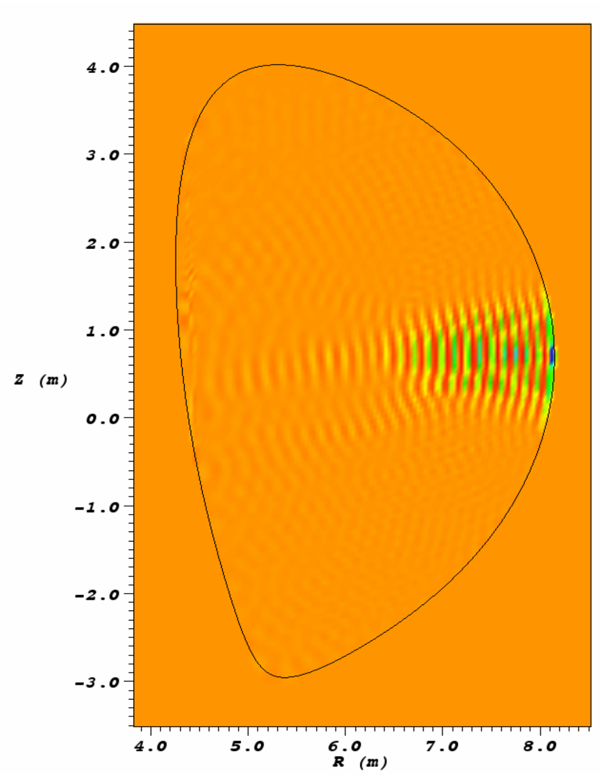
- **Do you have any special requirements (software/libraries/data storage/scientific workflow)?**
  - ScaLAPACK to invert our large dense complex matrix
  - NETCDF to transfer files from CQL3D to AORSA
  - PYTHON for iterating between CQL3D and AORSA
  - VISIT and PGPLOT visualization
  - SVN (Subversion) for version control
- **Do you have any special visualization needs?**
  - Visualize 3D wave fields in 3D toroidal geometry
  - Visualize the evolution of the 3D non-Maxwellian ion distributions functions as they change in time

Project logistics

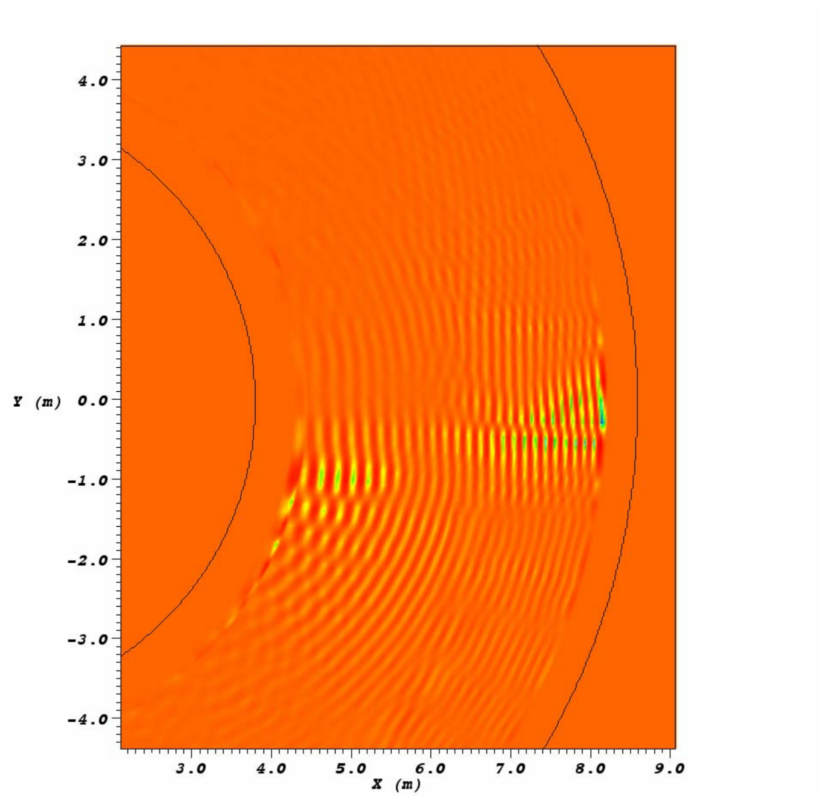
- **Do you have any special visualization needs?**

  Need to visualize 3D wave electric fields in 3D toroidal geometry

Poloidal plane



Equatorial plane

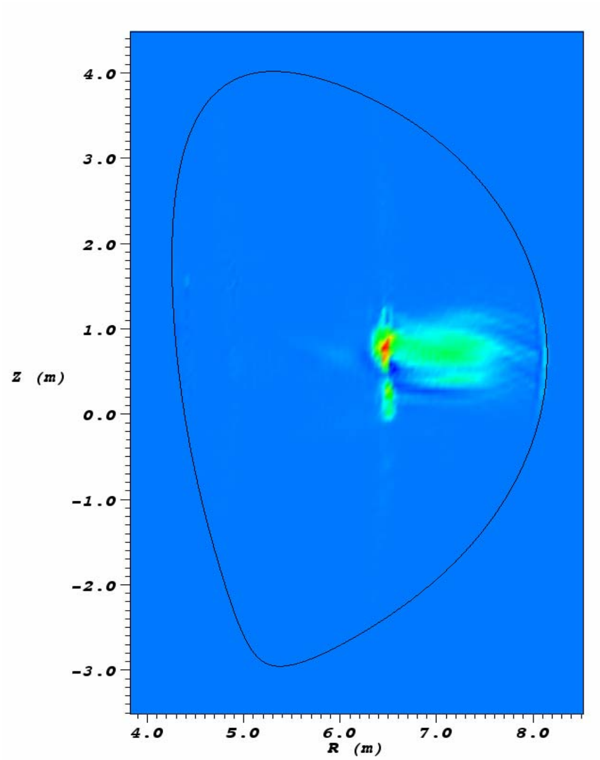


Project logistics

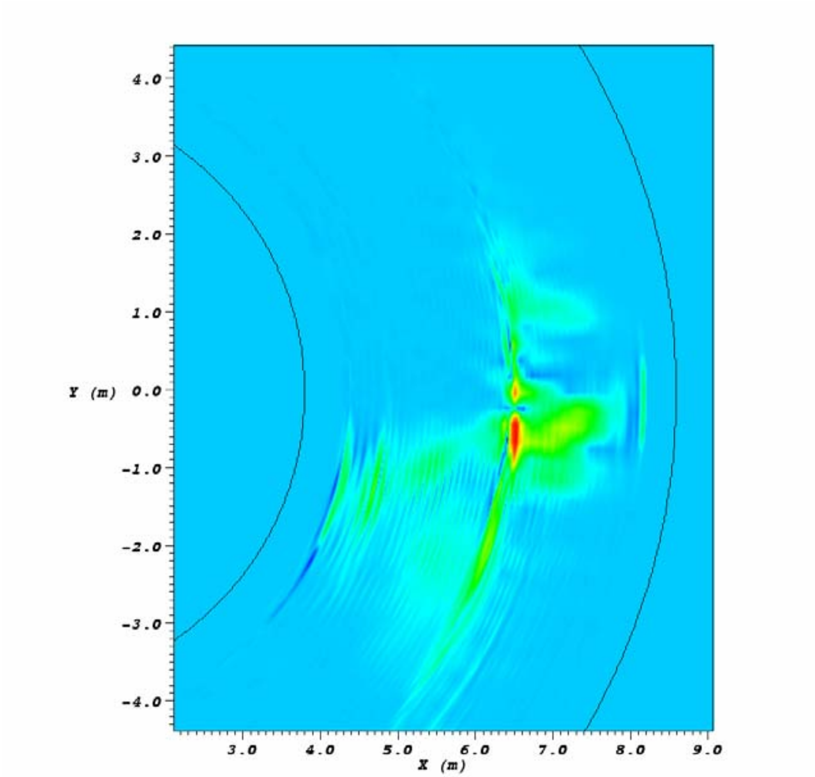
- **Do you have any special visualization needs?**

Need to visualize 3D power absorption in 3D toroidal geometry

Poloidal plane



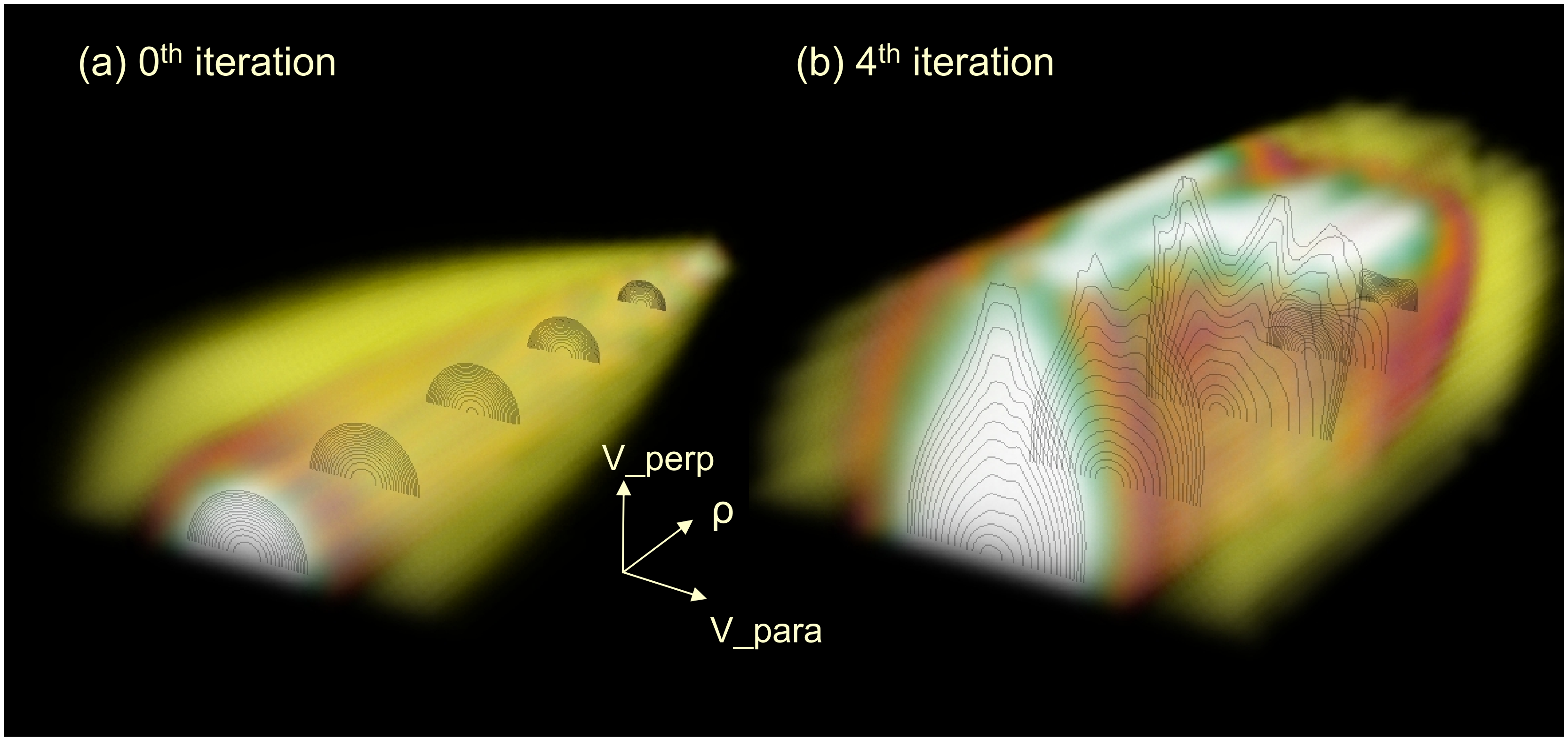
Equatorial plane



Project logistics

- **Do you have any special visualization needs?**

Visualize 3D ion distribution functions as they evolve (3D movie?)



Project logistics (continued)

- **What development efforts are required?**
  - We would like to couple AORSA to a Monte Carlo Fokker-Planck solver (ORBIT-RF) to include finite orbit effects left out of CQL3D
  - This will require passing a 4D file (3.7 GB for 128x128 mesh) of quasilinear coefficients to ORBIT-RF
- **What issues/problems do you anticipate as you begin production?**
  - Stability of the XT3 and running time for development
- **What level of interaction do you anticipate with the NCCS staff?**
  - Low to moderate overall; high with Vickie Lynch and Ed D’Azevedo